PUMP STATION OPTIMISATION

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OBJECTIVES

The aim of this paper is to highlight the fundamental principles for sewage pump station design improvements, provide practical examples on how to overcome technical and non-technical challenges and to demonstrate value for money approaches to minimize reconstruction, maintenance and operational costs.

It is essential to build pump stations that have long design life to maximize return on investments. With year 2010 approaching, many sewage pump stations being built in the 1970s are reaching the last decade of their operational life and will need improvement measures or complete reconstruction to provide an acceptable level of service. Typically, the improvement measures normally apply to mechanical equipment because the structures are usually sound. However, often the structures of the pumping facilities were designed inadequately to cope with the future demands and some systems were operating with problems right from the beginning. In such cases, replacement or reconstruction of these inadequately designed structures should also be considered rather than further investment to overcome difficult problems.

Typical structural problems of existing pump stations are:

- Poor site selection:
  - *Site constrains causing lack of storage space to cope with the increasing level of service (e.g. 4 hours to 8 hours ADWF emergency storage);*
  - *Lack of space for vehicular access;*
  - *Lack of space for operator access to wet wells and dry wells;*
  - *Confined spaces make maintenance and repair difficult and dangerous;*
- Insufficient energy dissipation arrangements affecting pumps performance;
- Shallow inlet chambers causing pump priming problems;
- Wet wells volume too small affecting the number of required pumps' start/stop cycles;
- Insufficient concrete cover to steel affecting the structure's corrosion protection performance;
- Arrangements for equipment removal and installation:
  - *Gantry beams, chain blocks and trolleys are often under-designed or not future-proof that causes safety concerns;*
- Inadequate ventilation provision, exposing structures to:
  - *H_2S attack to concrete and metallic surface;*
  - *Odors;*
- Noise issues caused by jam-packed equipment and lack of noise deafening arrangements.

Typical mechanical problems of existing sewage pump stations are:

- Incorrectly selected pumps affecting pumping system performance and causing excessive energy consumption;
- Poorly designed inlet pipework causing hydraulic losses leading to pumps' cavitations:
  - *Strainers on inlet side,*
  - *Shallow inlet pipes submergence;*
  - *Common inlet pipe for more than one pump;*
- Poorly designed outlet pipework and manifolds causing excessive hydraulic loses and difficult maintenance:
  - *Incorrect (Vertical) installation of flap type non-return valves*
  - *Manifolds without end access for cleaning blockages.*
- Incorrectly selected or installed flow measuring devices producing confusing readings. Specially dangerous if pumps' control uses flowmeter readings;
- Excessive use of Variable Speed Drives (VSD):
- Often VSD is used to improve design deficiency made during pumps selection, rising main sizing or wet wells sizing. The correctly designed pumping system should be able to operate without VSDs unless the delivery flows or pressures are excessively high.
- The VSD should be considered based on the following reasons:
  - *For achieving greater flexibility of a pumping system that avoids the so called "plug flows";*
  - *For deterrence of hydraulic hammer effects (by slow starts and slow stops) if the existing pumps were changed and it is more economical to use VSD instead of replacing existing rising mains;*
  - *For prevention of sudden power draw affecting properties in pump station neighborhood (by slow starts);*
  - *Noted that installation of VSD will not alleviate water hammer during power failure events, hence good design is still a paramount.*
- Screening facilities at inlet:
- Some of the large pump stations accept flows from large collectors (300mm diameter and more) that require screening of incoming sewage. For pipes up to 200mm diameter screening is generally not necessary as the installed pumps can cope with most incoming solids. Screens should be coarse, i.e. 40mm or more. Installed screens with gap less than 40mm are prone to cause blockages and require frequent cleaning.

Typical problems of existing sewage rising mains are:

- Selected pipe material:
  - *Material not suitable for long term contact with sewage;*
  - *Incorrect pressure and stiffness class of pipes;*
- Pipe route not allowing for easy access for maintenance or repair to air valves and scour valves. The lack of maintenance decreases pumping system efficiency and can potentially lead to eventual pipeline failure;
- Pipeline profile design is demanding excessive number of air valves, hence costly to build and maintain;
- Incorrect selection of air valves:
  - *Clean water air valves selected for sewage rising mains;*
  - *Single action air valves selected at incorrect positions;*
- Incorrect installation of air valves:
  - *Excessive spacing on the rising mains;*
  - *Incorrect positioning in the vicinity of the non return valves;*
  - *Incorrect valve sizing;*
  - *Incorrect "On pipe" installation without air collecting chamber (pot) and without cut-off valves.*

Typical problems of existing overflow structures:

- Causing erosion to stream/watercourse;
- Floatable solids not screened / untreated;
- Odour issues;
- Visual impact and environmental impact.

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FUNCTIONS OF PUMP STATIONS

All sewage pump stations have a common objective – to intercept incoming flows, provide temporarily storage and convey flows to the desired location and elevation as efficiently as possible. Optimal design will minimize maintenance work requirements and hence the operational costs can be planned with confidence, without large and unexpected repair costs due to severe system breakdowns and failures.

REQUIREMENTS FOR EFFICIENT PUMP STATION DESIGN

Dry Well or Wet Well Pumping System

There are two basic configurations of sewage pump stations:

- Dry well pump stations consist of a wet well and space to accommodate dry well pumps. This configuration is usually selected for large pumping facilities. Relatively high construction cost and large space are required.
- Wet well pump stations consist of a common wet well chamber that also accommodate pumps. They are generally cheaper in construction than the above configuration. With recent new development in submersible pumps manufacturing technology, this type of pump station becomes a popular choice for designers that offer cost effective solution and reliable performance.

Selection of pump station sumps construction methods

The selected construction method of pump station is associated with the size of the wet well sump, geological conditions and acceptable costs. In practice, there are three basic construction methods:

- Precast elements (circular or rectangular) are used for small to medium sized wet wells. Relatively quick construction enables less effort to be spent on control of ground water in excavations and the like, and is relatively cheaper than the following methods.
- Insitu casting method of construction is generally used for large sumps. The construction is executed either by a large open excavation or by drop shafts (caissons) if ground water becomes an issue.
- Mix of precast and insitu casting are used for very large wet wells. Recent development of the new sealing materials enable old and new (green) concrete to bond together effectively cost saving can be achieved. Vertical precast elements (usually slabs) are installed on cast insitu base slab and joined by insitu cast filling elements.

It should be recognized that pumping system consists of A) pump(s), B) wet well and C) rising main. These three elements should work in unison to maximize its efficiency.

A. Selection of pumps and their configuration

The selection of pumps should start from establishing the required systems' duty point incorporating head (pressure) and discharge (flow). Pumps suitable for sewage transfer:

- Centrifugal pumps – most popular choice, up to 60m total head and volumes up to 5,400m³/hr (1.5m³/s);
- Positive displacement pumps – for high heads but small volumes. Good for raw sewage or sludge transfer;
- Archimedean screw pumps – used mostly within treatment plants for large volumes and low heads (approx. 4-5m);
- Pneumatic arrangements – seldom used for their low efficiency (15-20%).

In NZ, most pump stations employ centrifugal pumps. Second common, apart from using pneumatic arrangements in tankers, are positive displacement pumps used for small pumping facilities. The centrifugal pumps can be installed in dry or wet wells. Positive displacement pumps are for dry well installation only.

There are two basic configurations for cooperating centrifugal pumps:

- Parallel – for large volumes and not excessive total pump heads;
- In series - for total pump heads acceding 60m. The "in series" installation or boosting pump stations are less common due to their complicated hydraulic issues.

B. Design of pump station wet well volume

In overall pump station wet well volume can be divided into two basic parts:

- Live volume - minimum volume complying with the pump manufacturer's requirements in terms of number of pump starts per hour. Live volume will be increased if the predetermined emergency storage volume is incorporated with the wet well.
- Dead volume - defined by the pump manufacturer's permanent pump or pump's intake (inlet) pipe submergence depth. This relates to priming conditions and avoidance of possible cavitation issues.

C. Rising Main Design

The rising main material shall be suitable for pumped medium and expected pressures. Surrounding environment is also a serious factor. Many rising mains were constructed in NZ without allowance for geothermal activities in the area. Rising main vertical alignment (long profile) should be a careful balance between depth of installation and number of air valves if the terrain configuration is complex. Scour points, if possible, should be avoided. They are costly in construction, difficult in operation, seldom used and if required usually not working because of valves not regularly used, tested and maintained.

Other Key Considerations for Pump Station Upgrades

The following issues shall also be considered in design:

- Suitability of selected site location (for example lake foreshore zone should be avoided to minimize sewage spill hazard to lakes).
- High corrosive environment.
- Structure utilization against the pumping system requirements (volumetrically-number of starts and allowance for pumps intake requirements).
- Suitability for accommodation of additional equipment. The existing wet wells are usually too tight for upgrade. Typically, being an old structure, the original design is not suitable for the new replacement pumps. In most cases, they are too small to allow for correct number of new pump starts and/or too shallow for new (usually larger) pumps. This can be improved by installation of additional manholes as storage to reduce the number of pump starts/stops.
- Wet well floor shape (allowing for transfer of sediment rather than collection within wet well).
- Suitability for maintenance and repair work while system in operation (gantry beams, dividing walls, ventilation, etc).
- Man access for equipment removal and transportation.
- Suitability of existing pumping equipment in relation to the existing and future flows. The pump should be selected for the designed application. Sizes and types of solids, volumes and head requirements dictate the impeller selection. Volumes and head also dictate the motor size selection. The pumps can be fine-tuned by changing the impeller size.
- Hydraulic analyses of overall system cooperation (pumps + rising mains system assessment).